

AIRS SST Measurements

Using RTG.SST in support of validation,
cloud filtering
and finding marine aerosol.

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Why use the ocean surface for validation?

The buoy measurements are the primary standard at the 0.1K level.

A number sea surface temperature products use buoys and IR to create daily /weekly global maps with less than 0.1K global bias relative to the buoys.

The ocean surface temperatures are the only product where the debate about the veracity of the numbers is carried out at the 0.5K level and less.

The ocean surface is thus an excellent target to validate the radiometric precision of AIRS.

We compared SST2616 with the RTG.SST

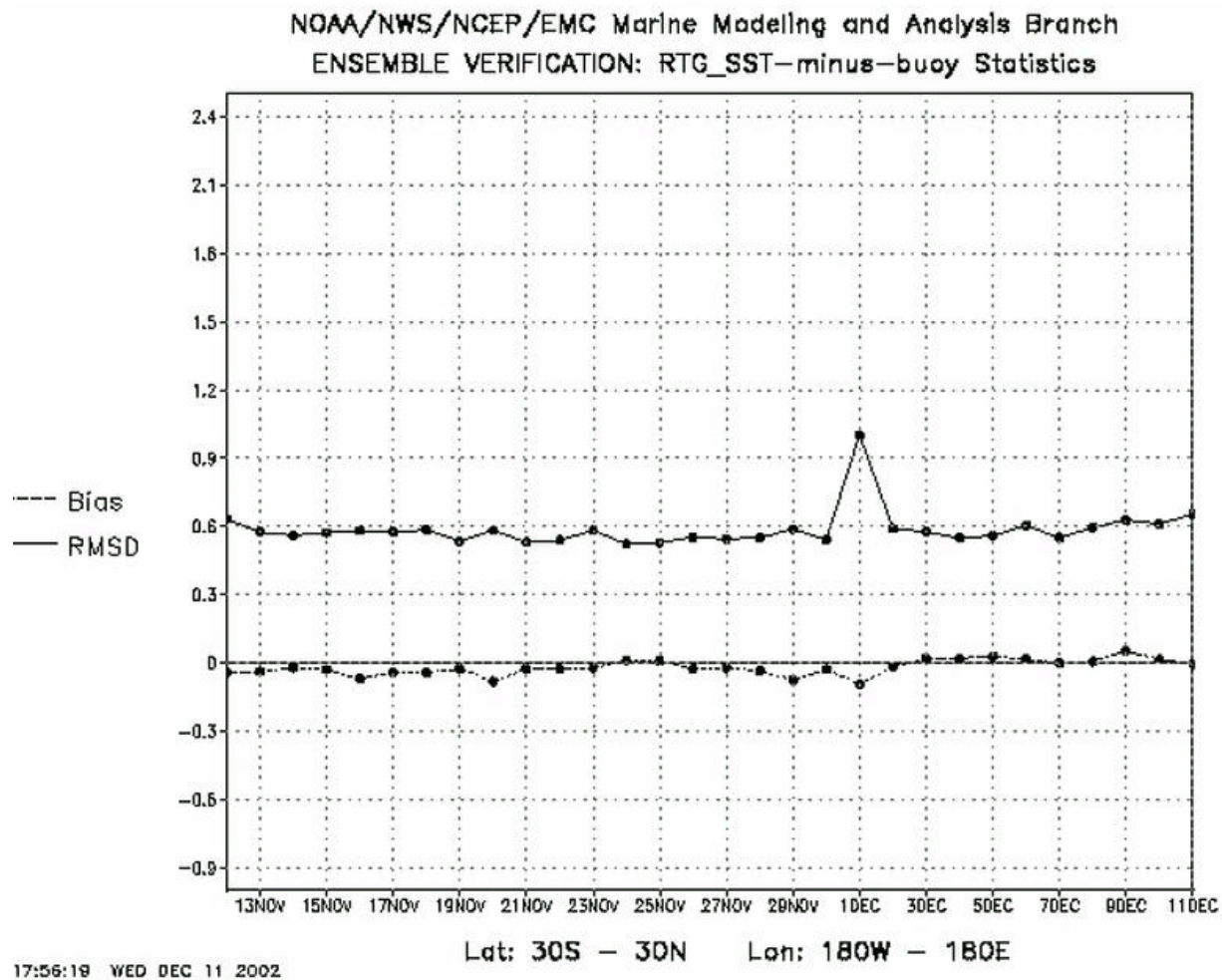
The RTG.SST is the Real-Time-Global Sea Surface Temperature produced by NCEP using optimal interpolation of buoy data, ship observations and SST retrievals from spacecraft, mostly AVHRR, on a $\frac{1}{2}$ degree grid.

Since the rtg.sst represents the day/night average temperature of the ocean at the buoy level, at night the data will be 0.15K warmer than the buoy due to the diurnal variation in the thermocline, i.e.
 $(\text{buoy} - \text{rtg}) = -0.15 \pm 0.05\text{K}$

In addition, the skin at night is statistically about 0.15K colder than the buoy due to evaporative skin cooling, i.e.
 $(\text{skin} - \text{buoy}) = -0.15\text{K} \pm 0.05\text{K}$

AIRS sst2616 and sst1231 measure the skin temperature.
For cloud free pixels we expect
 $(\text{skin} - \text{rtg}) = -0.3 \pm 0.1\text{K}$

30 day sliding window validation of the rtg.sst relative to buoys shows a global bias of less than 0.05K and stdev=0.4K.



SST Measurements with AIRS

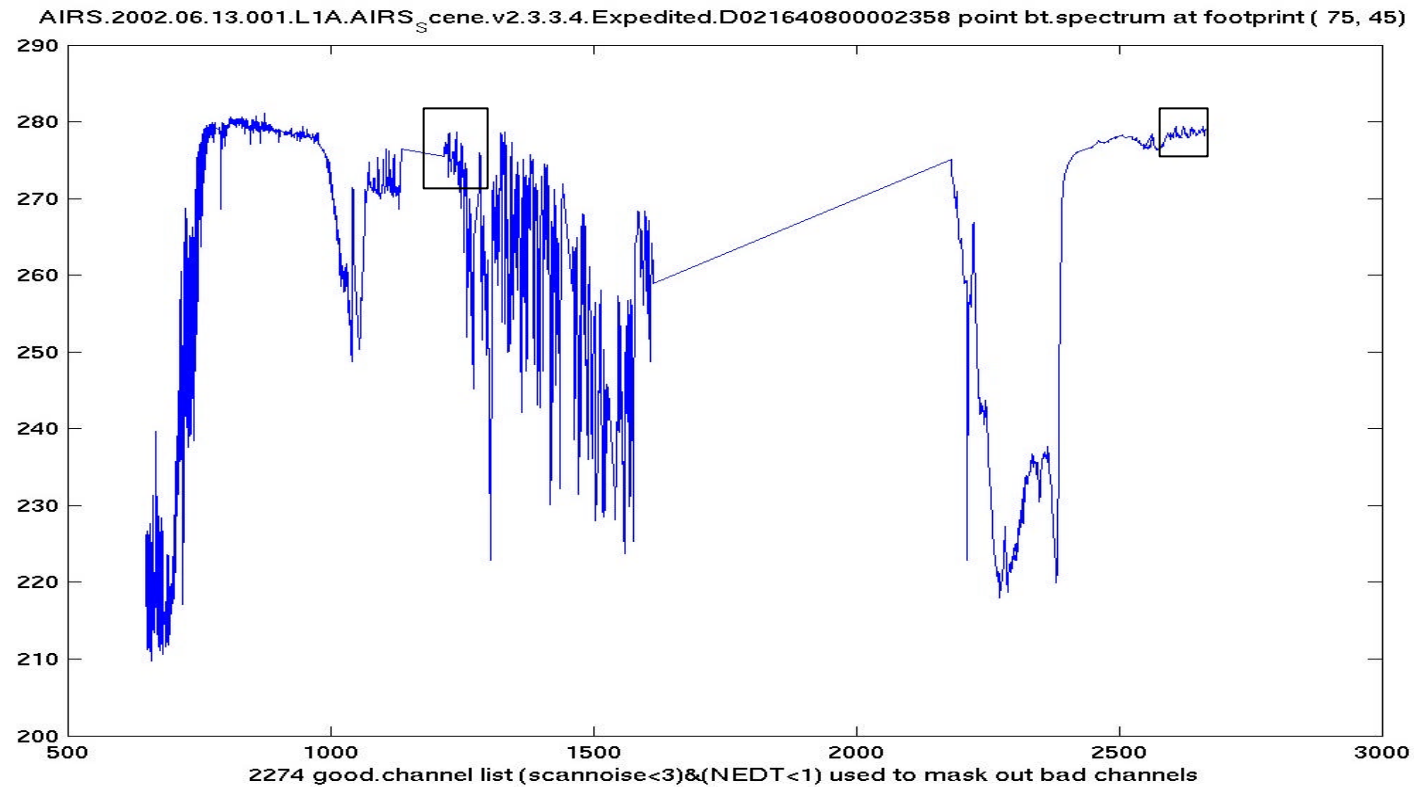
AIRS has 2378 spectral channels.

Spectral resolution is $\nu/\Delta\nu = 1200$

Typical NEDT = 0.2K for 250K scene

For the use of the sea surface temperature for validation we use only four channels

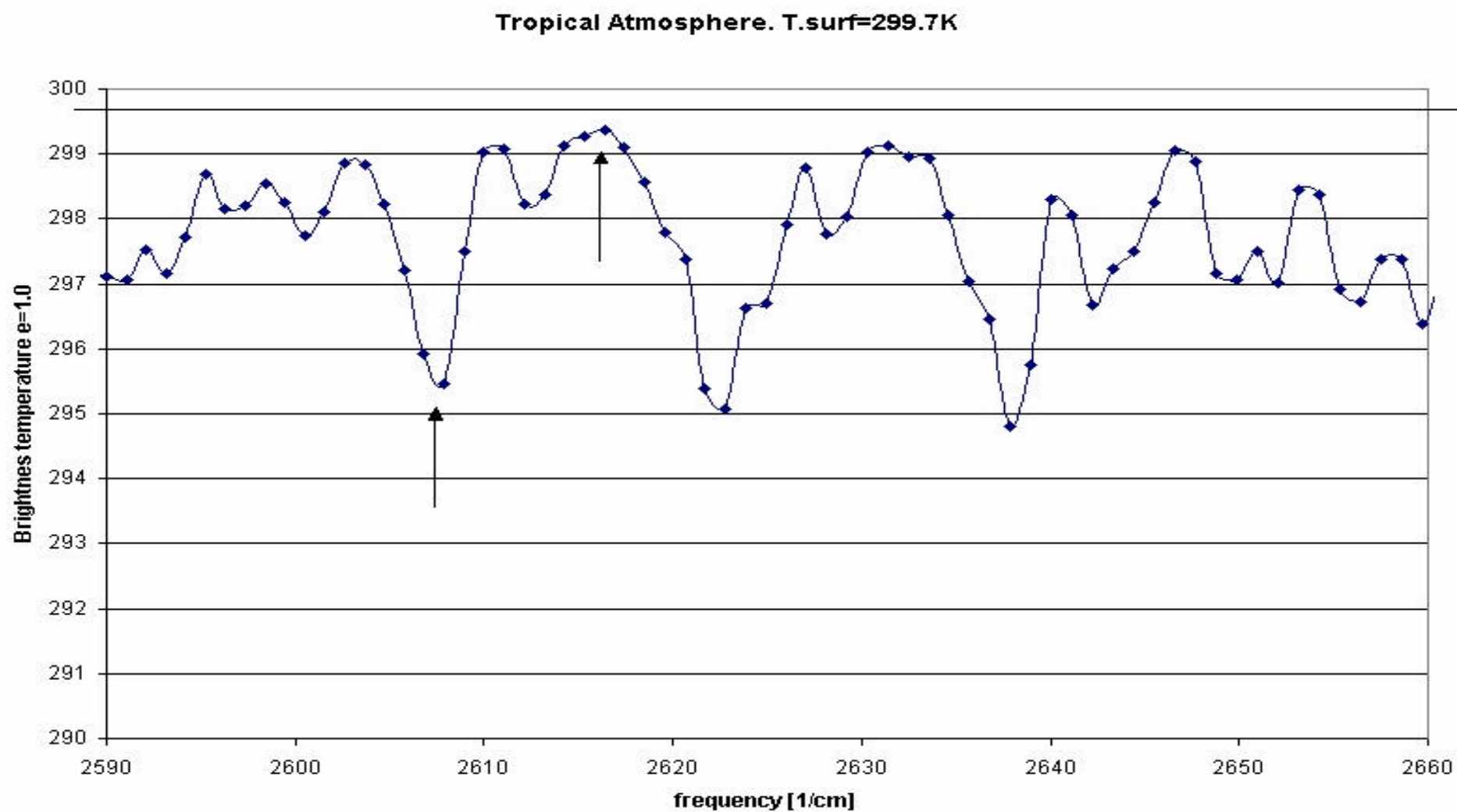
- 1) sst2616 uses the window channel at 2616 cm⁻¹
combined with the waterline at 2607 cm⁻¹
- 2) sst1231 uses the window channel at 1231cm⁻¹
combined with the water line at 1238 cm⁻¹



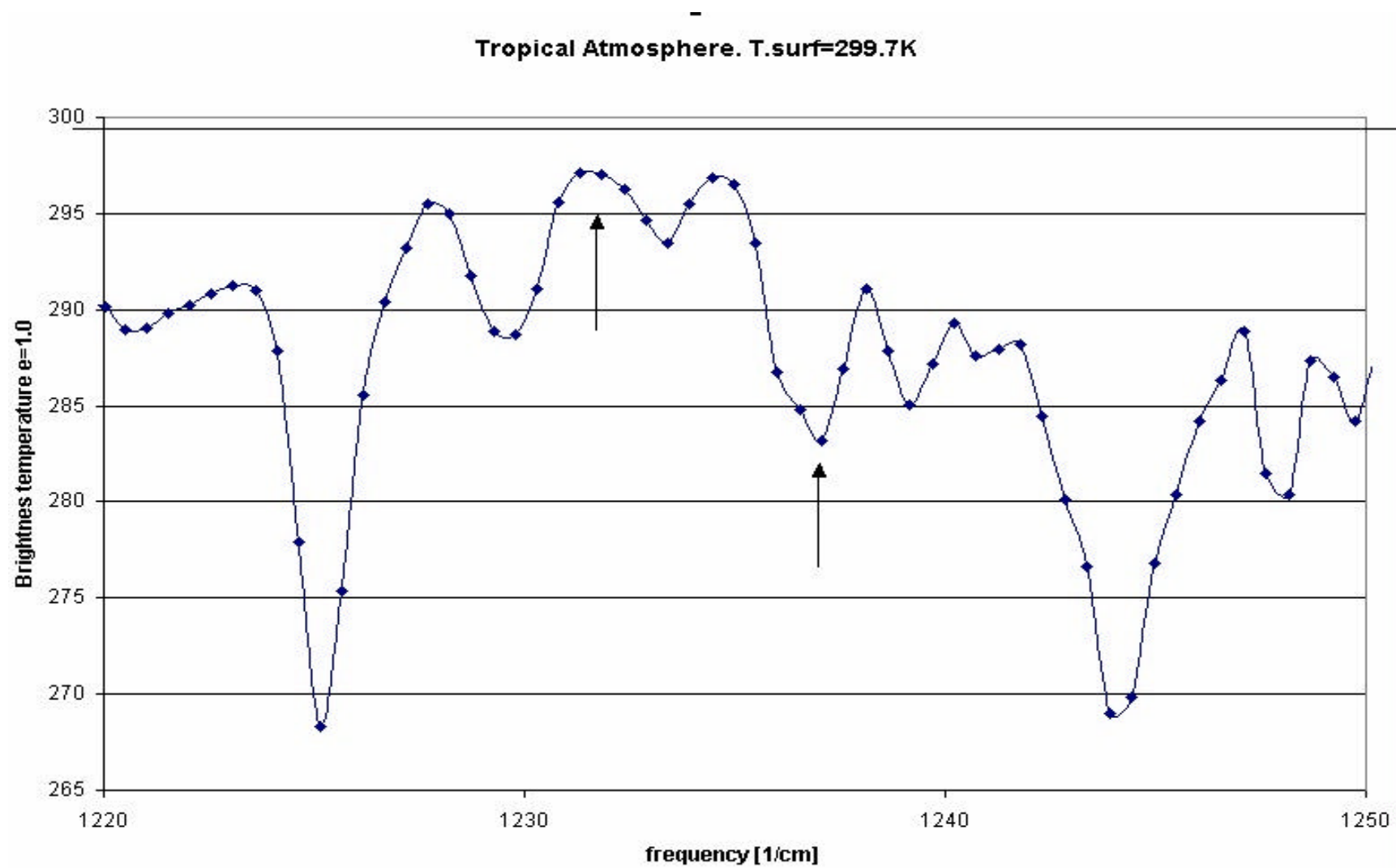
A typical spectrum with a 2378 channels.

Next we will zoom in on the two boxes which identify the 1231 and 2616cm⁻¹ regions

SST2616 is derived from the brightness temperatures at 2616 and 2607 cm^{-1}



SST1231 is derived from the brightness temperatures at 1231 and 1238 cm⁻¹



$$\text{sst2616} = \text{bt2616} + f(\text{bt2616} - \text{bt2607}, e(\text{sza}, v))$$

sst2616 is the sea surface skin temperature at 2616 cm⁻¹

$e(\text{sza}, v)$ = numerical fit to Mazuda emissivity at 2616 cm⁻¹
as function of sza at wind velocity v [m/s]=3m/s

Use Strow January 2003 to work out the functional dependence using 6 representative climatologies

Crazy hot and wet	T.surf=308K
Tropical ocean	T.surf=299.7K
Mid.Lat.Summer	T.surf=294.2
SubArctic Summer	T.surf=287.2
Mid.Lat.Winter	T.surf=272.2K
Sub.Arctic Winter	T.surf=257.2K

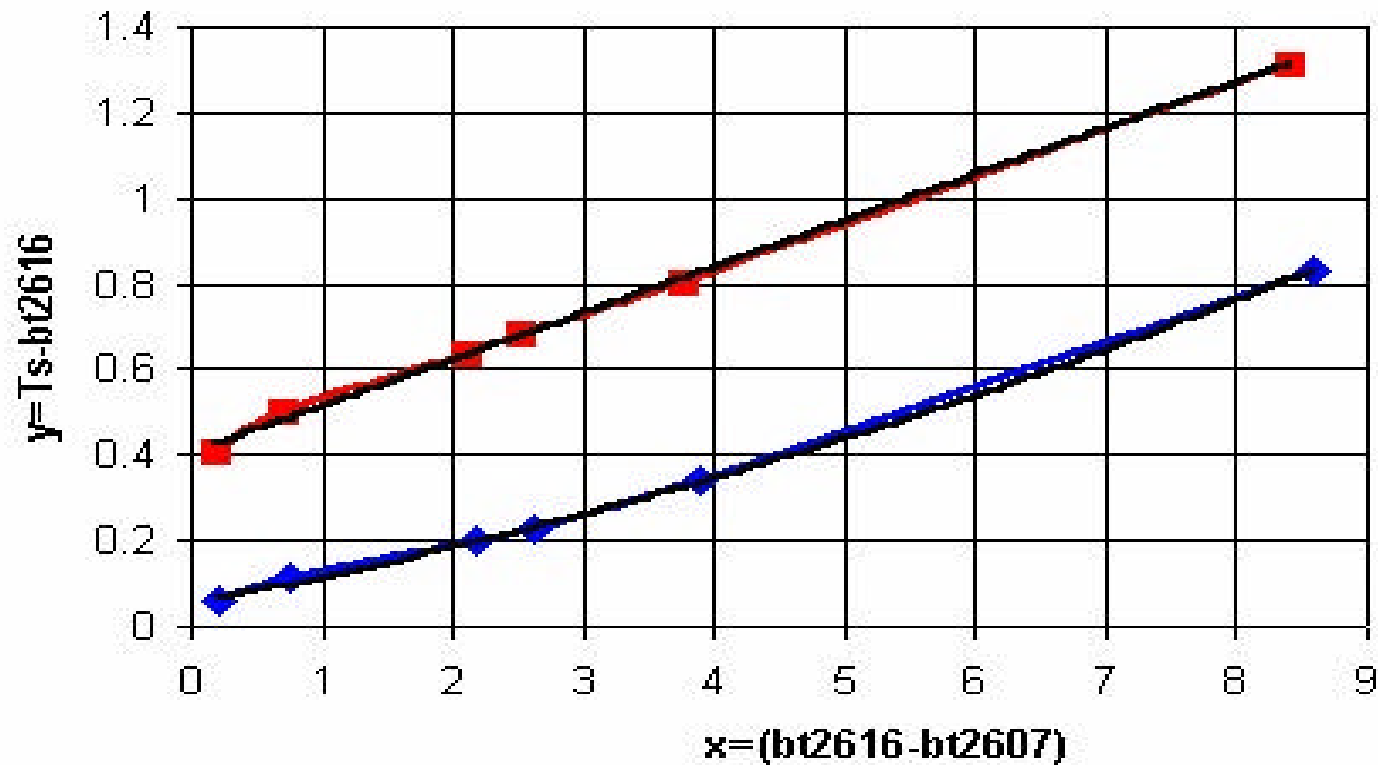
sza = satellite zenith angle (-56 < sza < 56 degree for AIRS)

Atmospheric Transmission and Emissivity Correction uses
six climatologies (c6) calculated with the January 2003 Strow RTA

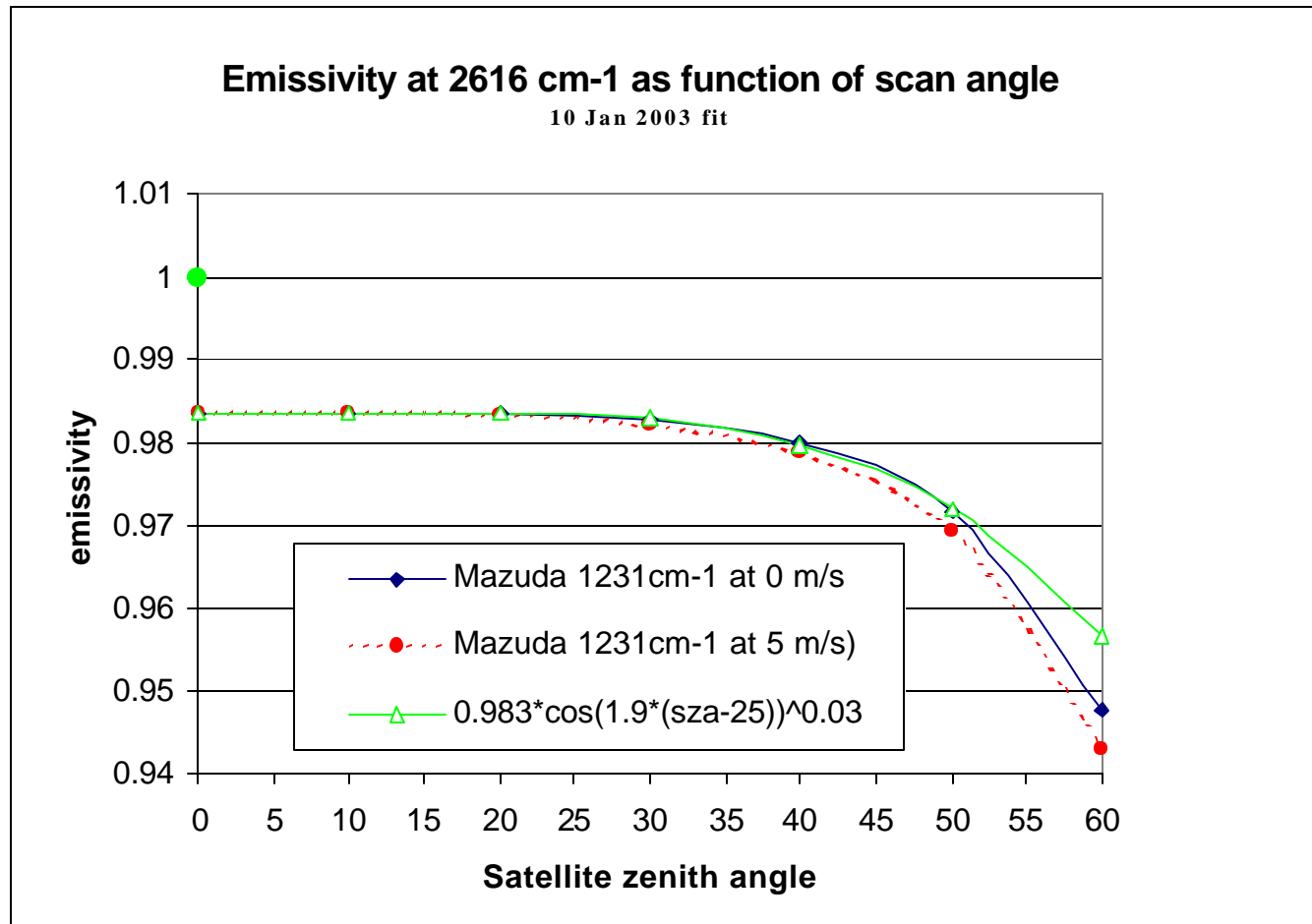
Atmospheric Transmission Correction

$$e=0.98 \quad y = -0.000053x^2 + 0.108460x + 0.407504$$

$$e=1.00 \quad y = 0.003795x^2 + 0.058141x + 0.054400$$



Ocean Emissivity at 2616 cm⁻¹ as function of zenith angle (Mazuda 1986)



There are some questions about the accuracy of this model at $\text{sza} > 35^\circ$ and wind. UKMeto uses Phil Watts (2002).

Matlab code fragment which shows details of the sst2616 and sst1231 algorithm

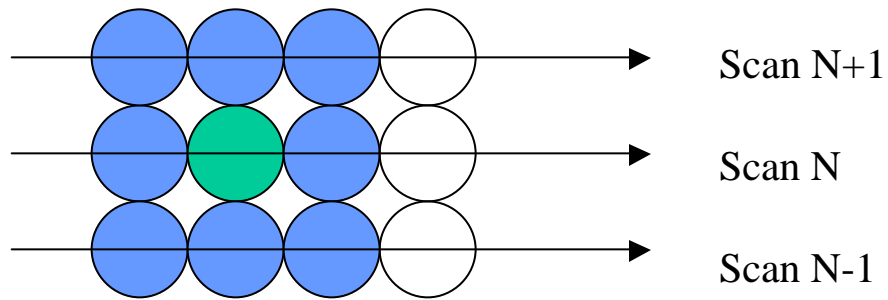
```
disp('sst1231 from Jan 2003 RTA');
d1237=bt1231s-bt1237s;
a1231_1=-0.1493+0.1493.*d1237-0.0217.*(d1237.^2)+0.001802.*(d1237.^3);
a1231_98=0.4214+0.19714.*d1237-0.022696.*(d1237.^2)+0.001791.*(d1237.^3);
a1231e=a1231_1+(a1231_98-a1231_1).*(0.983.*e1231-1)./(0.98-1);
disp(['Mean 1231 cm-1 emissivity correction = ' num2str(mean(a1231e(:)-a1231_1(:))) ]);
sst1231c6=bt1231s+a1231e;
%
disp('sst2616 from Jan 2003 RTA');
d2607=bt2616s-bt2607s;
a2616_1=0.052+0.05289.*d2607+0.002545.*(d2607.^2);
a2616_98=0.4075+0.10846.*d2607-0.000053.*(d2607.^2);
a2616e=a2616_1+(a2616_98-a2616_1).*(0.976.*e2616-1)./(0.98-1);
disp(['Mean 2616 cm-1 emissivity correction = ' num2str(mean(a2616e(:)-a2616_1(:))) ]);
sst2616c6=bt2616s+a2616e;
```

The in-depth evaluation of potential instrumental and/or radiative transfer algorithm effects requires cloud free data.

An AIRS footprint is declared to be free of clouds if it passes two tests:

1) the spatial coherence test

2) the low stratus cloud test



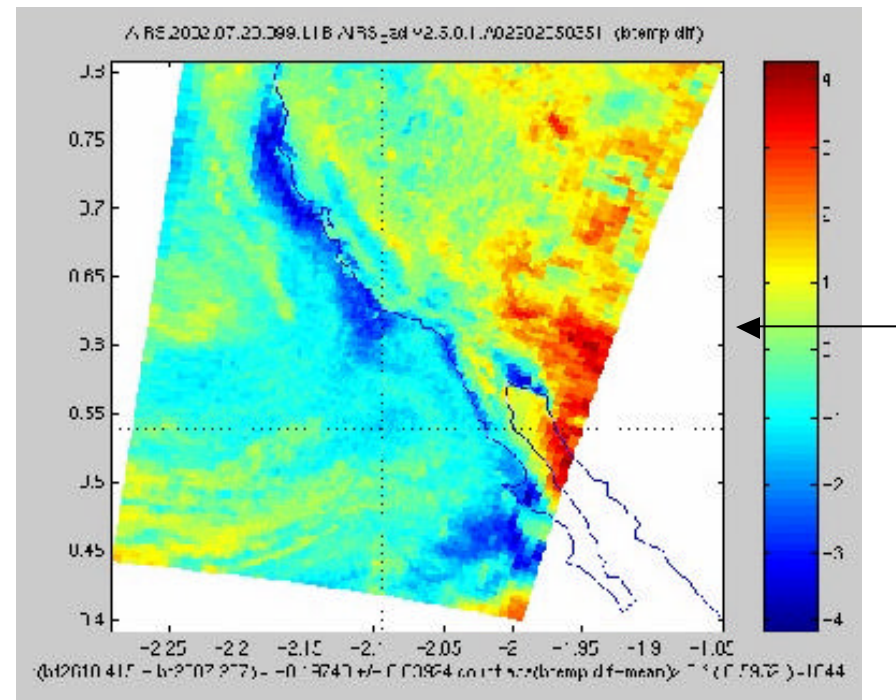
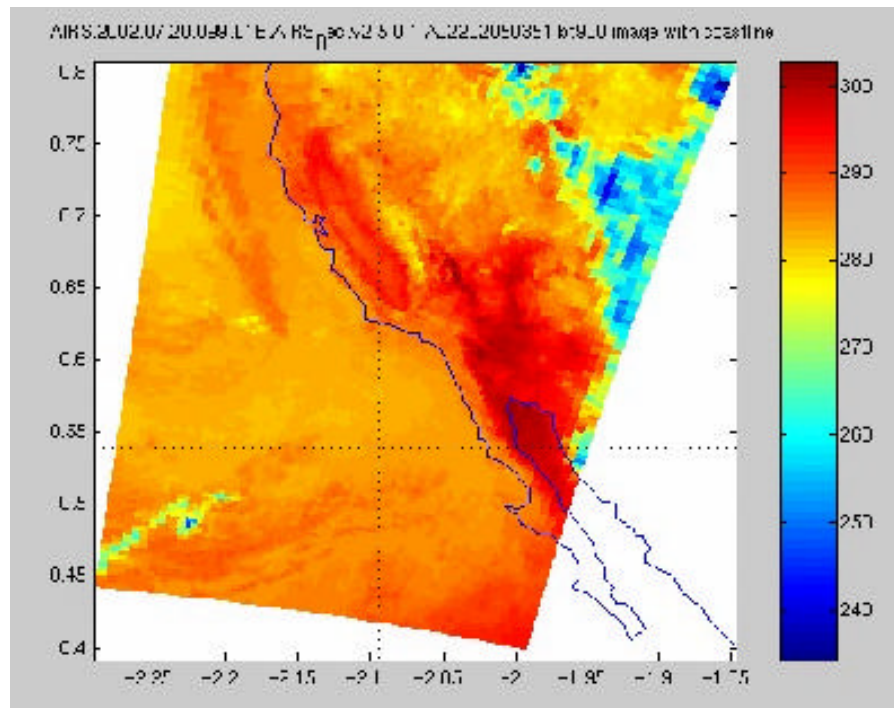
The spatial coherence test uses a 3 x 3 pattern of nine AIRS footprints. The center footprint passes the test if (max - min) of the nine footprints is less than the threshold SC2T.

$$\text{Residual cloud contamination } E \sim (\text{SC2T} - 3 \cdot \text{NEDT})/3$$

Residual cloud contamination can be estimated using SC2T as a parameter.

For $\text{SC2T} = 0.5\text{K}$ and $\text{NEDT}(2616\text{cm}^{-1}, 300\text{K}) = 0.07\text{ K}$, $E \sim 0.1\text{ K}$

Low stratus clouds which pass the spatial coherence test
are detected using their effect on weak water lines



AIRS footprints are rejected as low stratus contaminated if

$$(bt2616-bt2607)<1 \text{ K}$$

Only 0.5% of the AIRS night ocean footprints pass the $sc2t=0.5K$ spatial coherence and low stratus test.

90% of the AIRS clear pixels are also MODIS clear for all MODIS subpixels

The spatial coherence/stratus test has been compared to the MODIS cloud flag for 29 September 2002 night
180 < longitude < 360 degree ocean data.

Sc2t threshold	AIRS clear on MODIS position	all MODIS sub pixels clear	%
1.00	14451	10083	70%
0.7	7412	5974	80%
0.5	3577	3148	90%
0.4	2121	1926	91%

Only 0.5% of the AIRS footprints pass the sc2t=0.5K spatial coherence and low stratus test. This corresponds to about 8000 clear footprints globally per night, 240,000 per month.

Analysis of monthly data set should be statistically stable.

The next slide shows what happens when we take the 240,000 “clear” footprints to create a map between +/- 50 degree latitude with 2x2 degree cells for September 2002.

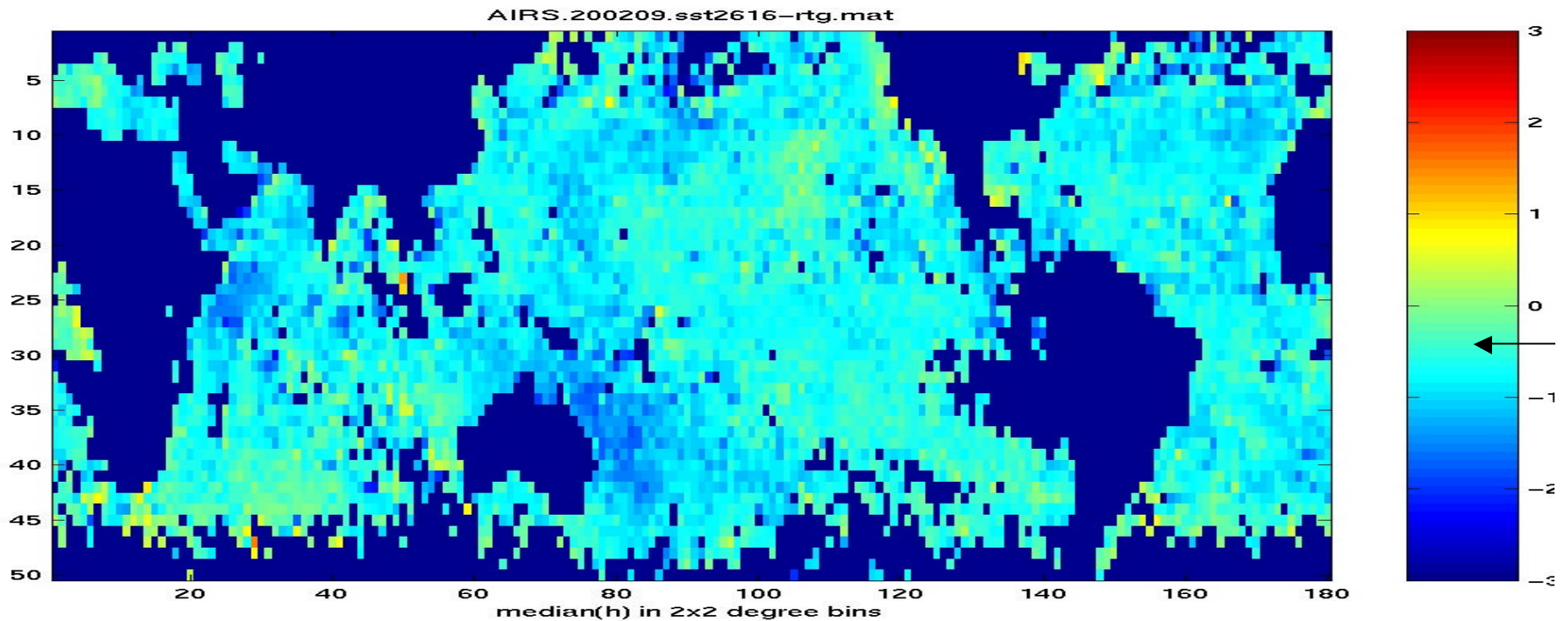
For each cell population we calculate the median, the 68% population standard deviation and the population count. If the cell contains less than two entries we set stdev=-1.

There are 5500 ocean cells in this map, i.e. $240,000/5500 = 44$ entries per cell. The actual count is 5266 cells with between 2 and 1076 entries. Median is 27 entries.

The slide shows (sst2616-rtg.sst)

The color scale ranges from -3 degrees to + 3 degree.

Over many areas of the globe we observe the expected -0.3K bias relative to the rtg.sst



There are large ocean patches with up to -2K cold bias,
and a few areas with +0.5K warm bias.

Next we show sst2616 and sst1231 maps for

September 2002

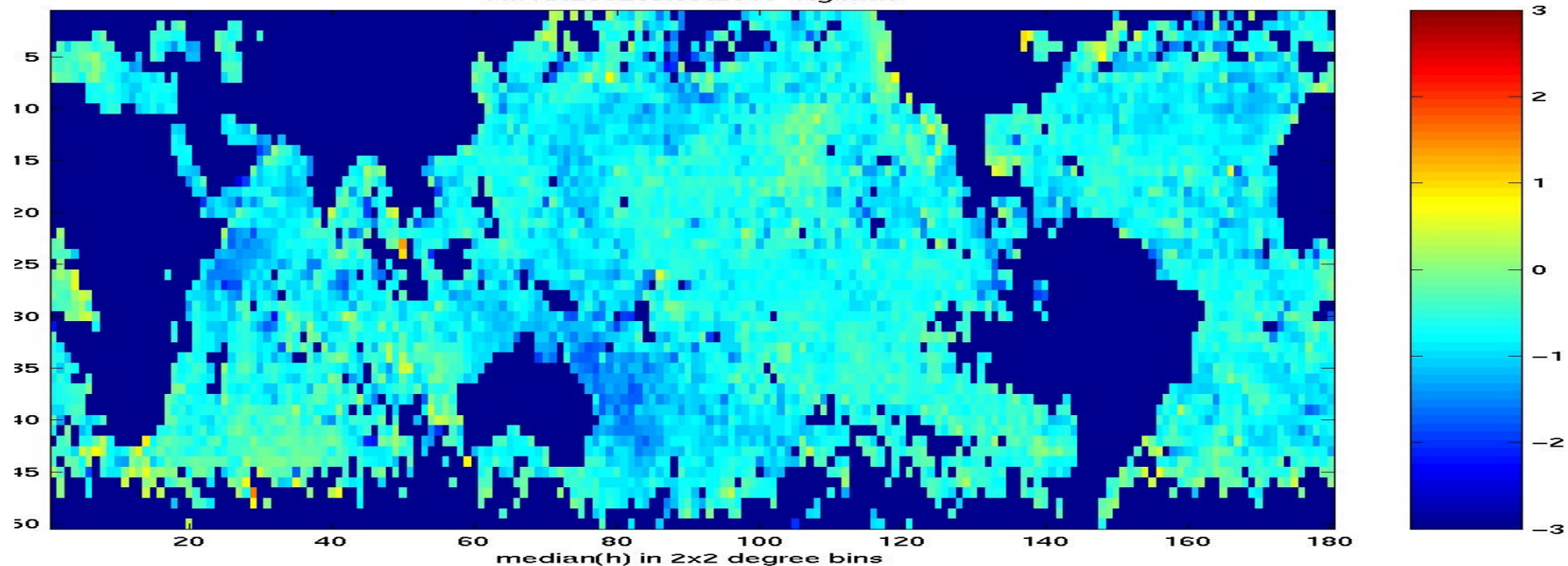
October 2002

There are large areas where sst2616 agrees with sst1231 within a small fraction of a degree.

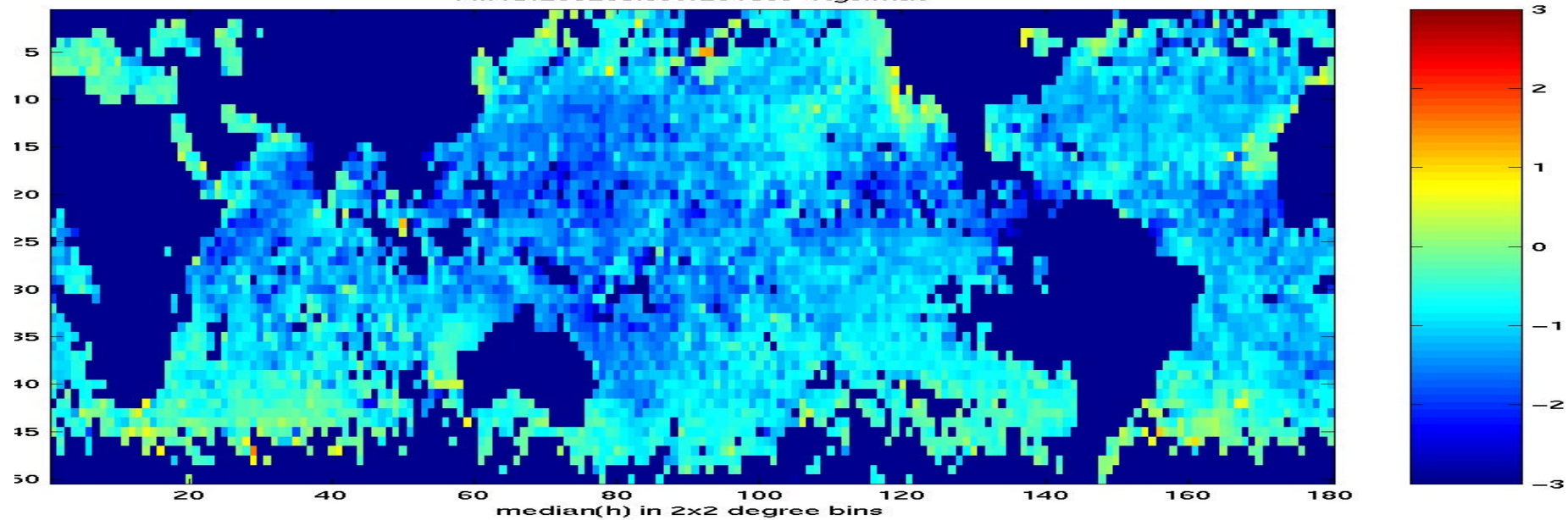
The ocean patches where sst2616 showed up to -2K cold bias cover a large fraction of the tropical oceans

Large regional month-to-month changes (variability? Transport?)

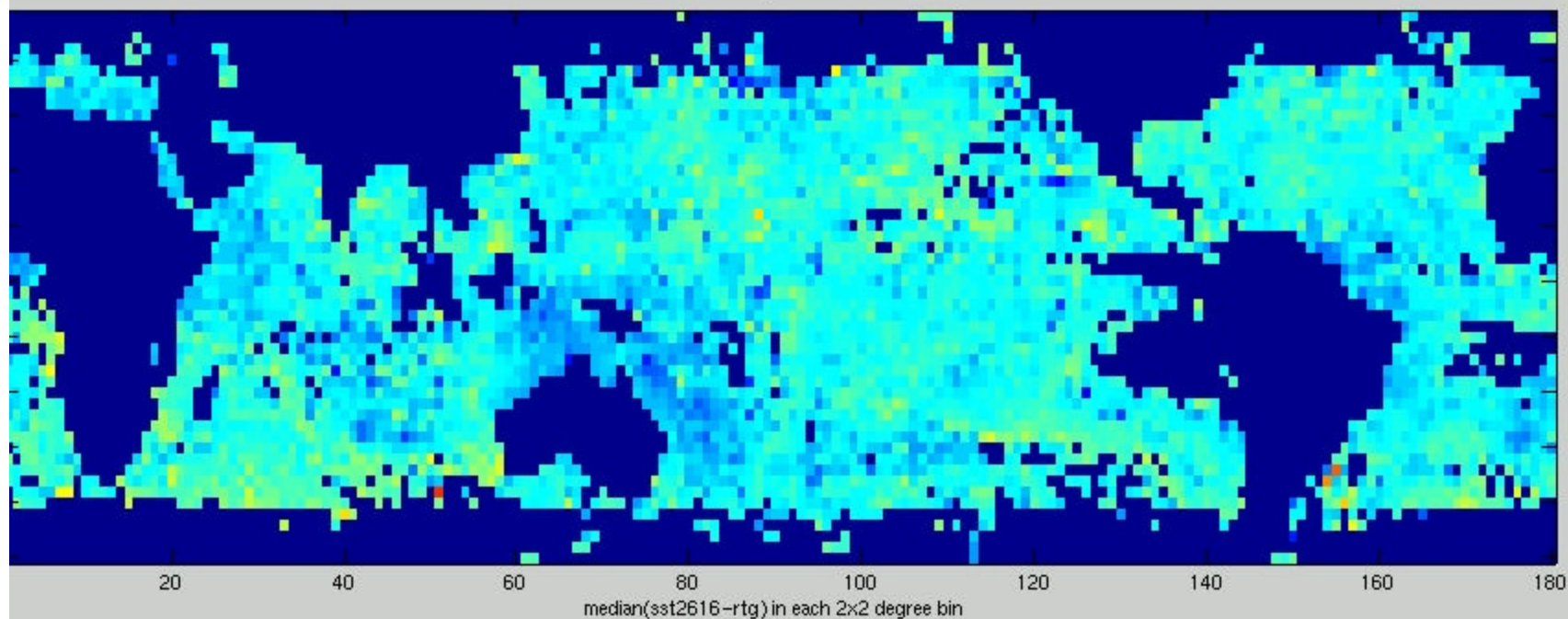
AIRS.200209.sst2616-rtg.mat



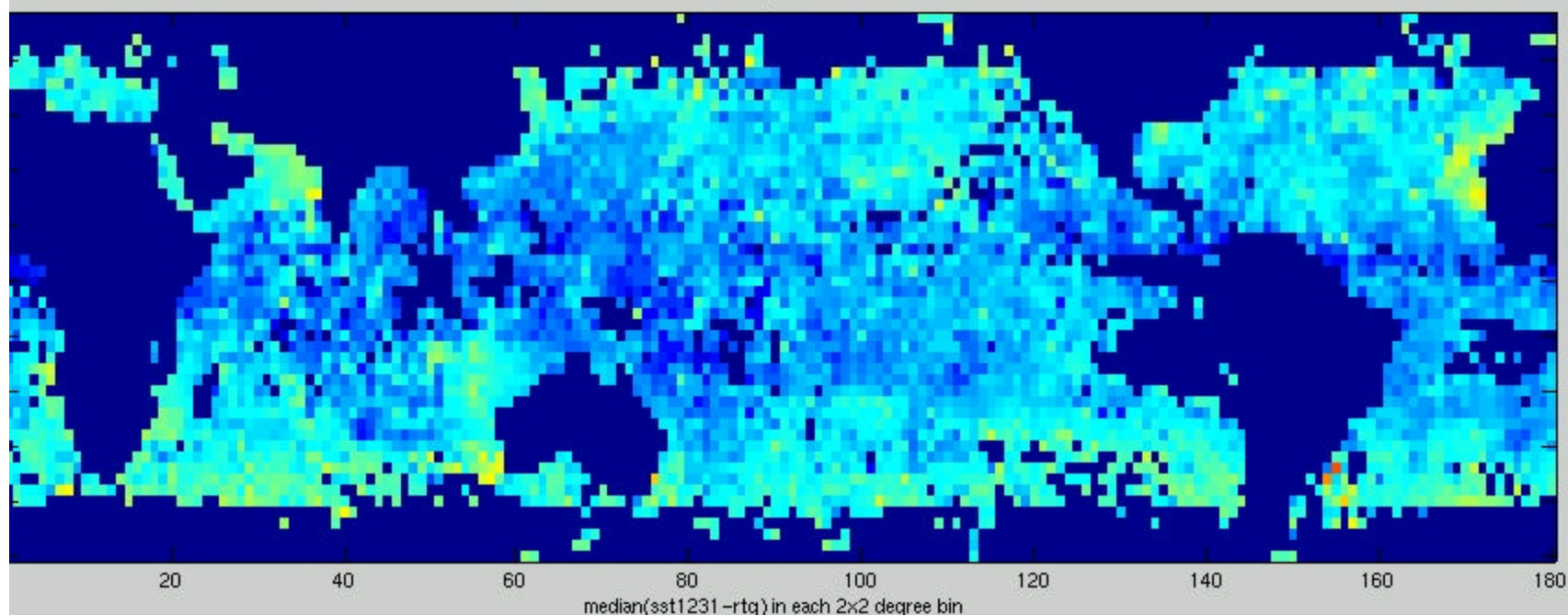
AIRS.200209.sst1231c6s-rtgs.mat



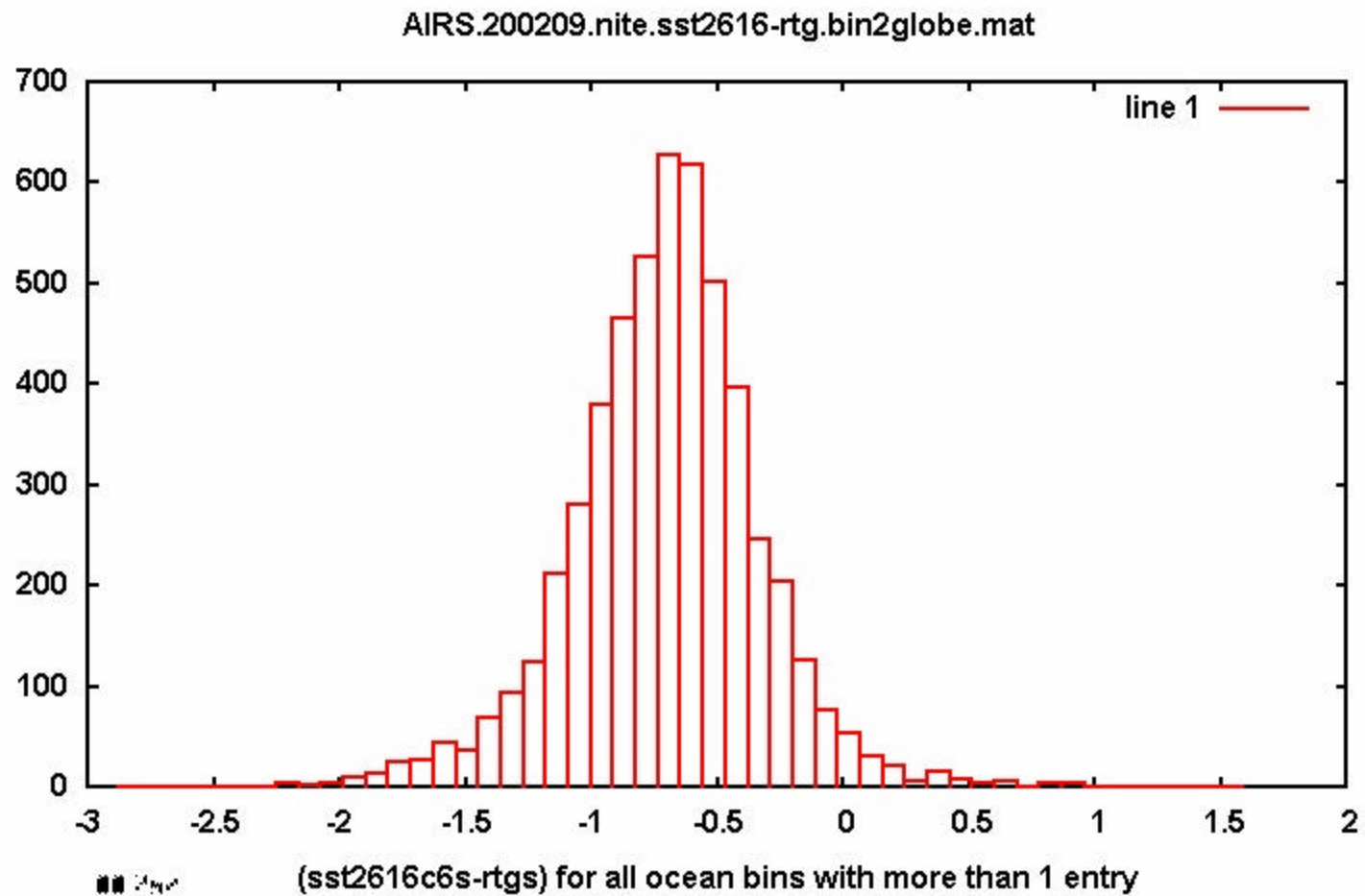
AIRS.200210.01-31.db.stack_{ig2f}.nite.sst2616.bin2globe.mat



AIRS.200210.01-31.db.stack_{ig2f}.nite.sst1231.bin2globe.mat



Global ocean bin statistics
(sst2616-rtg) = -0.69 +/- 0.31K



Statistics of the 240,000 clear footprints for September 2002.

(sst2616-rtg.sst) shows a strong temperature dependence.

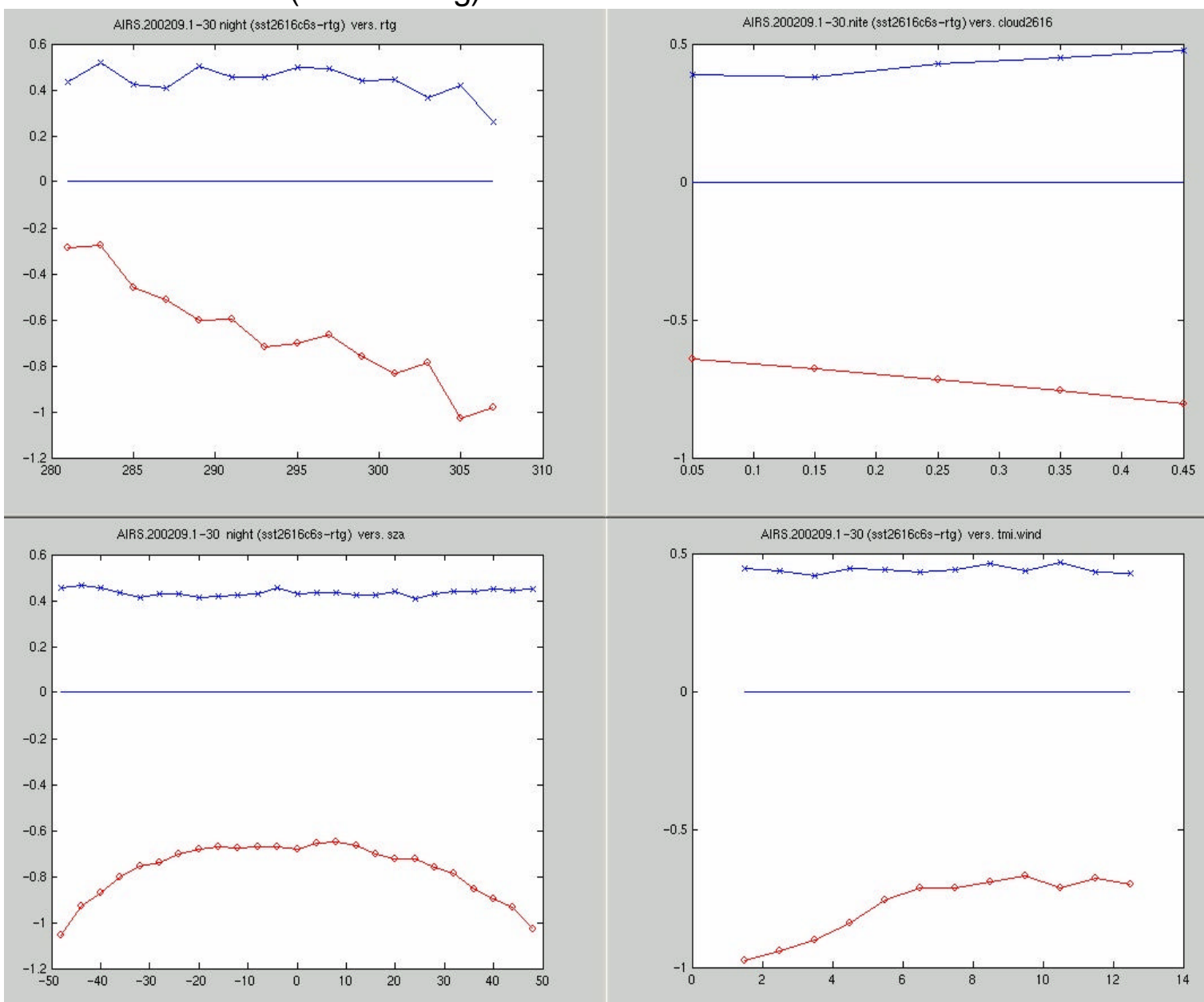
AT 280K the bias is equal to the expected -0.3K bias.

The bias increases almost linear with temperature to -1K bias at 305K

(sst2616-rtg.sst) shows the $1/\cos(\text{sza})$ dependence characteristics of an absorbing atmospheric layer

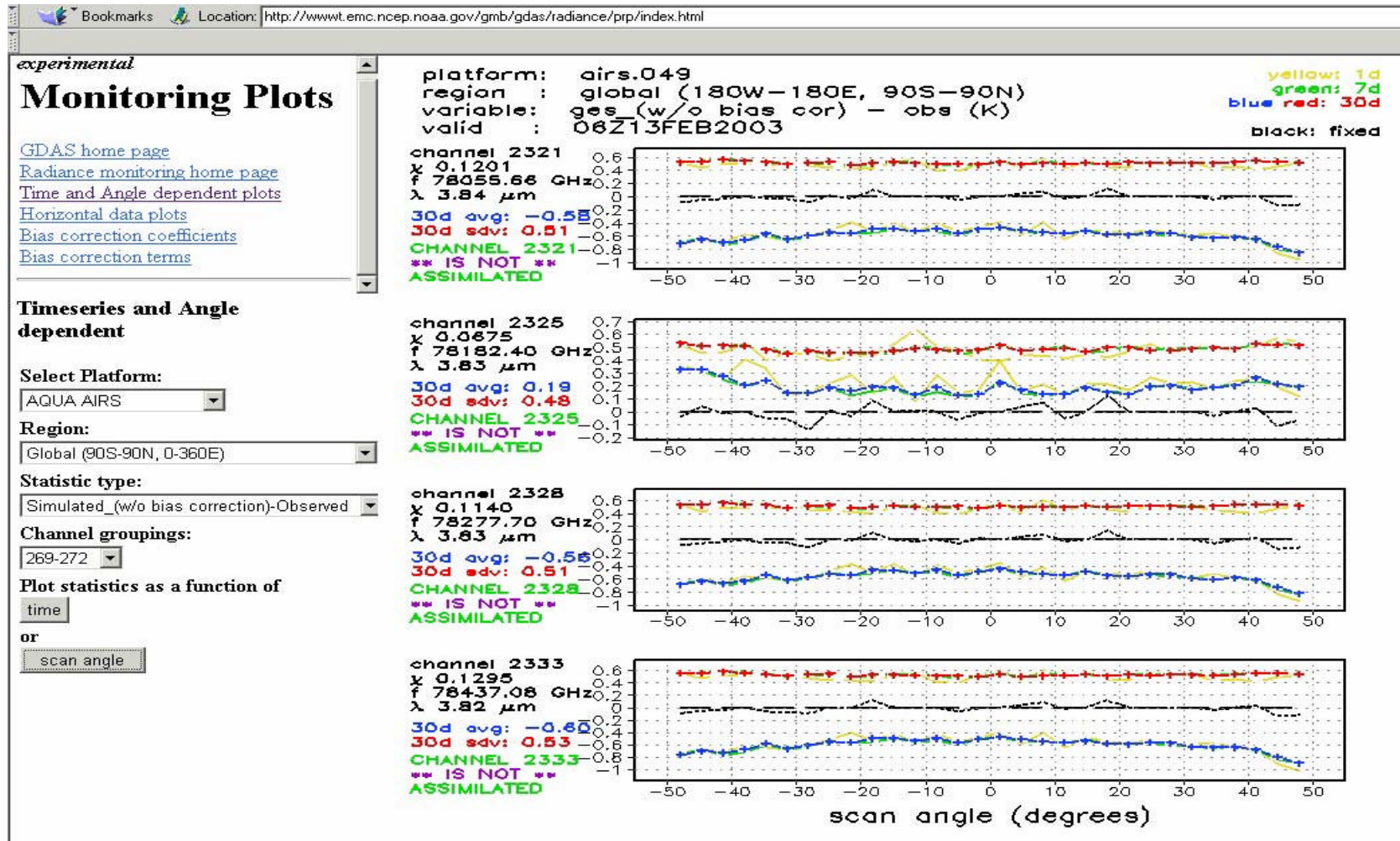
(sst2616-rtg.sst) shows the expected wind speed dependence, but with a 0.6K offset.

$(\text{sst2616-rtg}) = -0.3\text{K} \pm 0.4\text{K}$ at $T=280\text{K}$



The global (sst2616-rtg.sst) shows a strong $T.\text{surf}$ and sza dependence

The scan angle dependence of (Obs.-calc.) at 2616cm-1 is clearly visible in the NCEP Monitoring plots, which use a different cloud filter.



Conclusions for validation:

For 240,000 “clear” night ocean footprints of September 2002

The global bin statistics of (sst2616c6-rtg.sst) give median=-0.69K stdev= 0.30K.
This is 0.4K colder than the expected -0.3K bias.

The “clear” pixels contain an additional 2616cm⁻¹ absorber at the 0.4K level

The global bin statistics of (sst2616c6-sst1231) give median=0.32K stdev= 0.37K.

The “clear” pixels contain an additional 1231cm⁻¹ absorber at the 0.7K level.

What to conclude from this is complicated by water continuum correction uncertainties.

The distribution of pixels with additional absorber shows monthly variability on a large spatial scale.

As far as validation of level 1b and the radiative transfer are concerned this is an excellent result. The radiometric calibration at 2616cm⁻¹ is better than 0.3K for the 280K - 300K scene temperature range.

Whatever causes the regional cold bias is a research issue.

Oceanographic conclusions

A 2x2 degree global map for September 2002 shows that the cause of the unexpected cold bias is spatially correlated on the 1000 km scale and causes up to 2K cold bias relative to the rtg.sst..

The effect has the characteristic $1/\cos(\text{sza})$ dependence of an atmospheric layer.

The effect is strongly temperature dependent. The warmer the surface the larger the bias.

There is month to month variability on a large spatial scale.

A sequence of 12 months should show if there is time correlated motion (transport?) ..

In areas where sst2616 is effected, the effect is twice as strong at 1231cm-1 in the cold bias..

We speculate that we are seeing marine aerosol about 10-20K colder than the surface with optical depth ranging from zero to 0.03. (median 0.015) The high spectral resolution of AIRS will be used for diagnostics.

Absorption with optical depth of 0.03 should be straight forward to detect in up-looking IR radiometry in the 4 micron and 10 micron atmospheric windows and using stellar photometry (visible and IR)..

There are large areas (1000 x 1000 km) where sst2616 and sst1231 are up to 1.5K warmer than the rtg.sst. The reason for this is unexplained.